Ozone Protects from Ultraviolet Rays

Healing the "Hole"

Garry Toth and Don Hillger

Ozone (O_3) is a molecule consisting of three oxygen atoms (Croatia, 1999/*Scott* 408), whereas the oxygen we breathe is composed of two oxygen atoms. Ozone is found in minute quantities in the atmosphere. What do we know about ozone? Why is ozone important? What is the ozone hole? This article will examine these questions through the perspective of stamps.

Early Research into Ozone

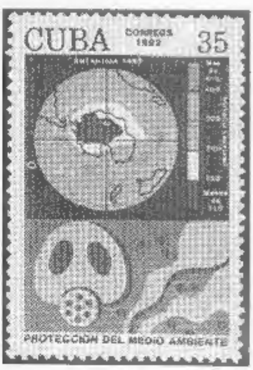
In 1785, Dutch chemist Martinus van Marum (1750-1837) noted an unusual smell during his experiments with electrical sparking above water, and attributed it to the electrical reactions. He had created ozone, but he did not identify it as a particular form of oxygen. During similar experiments in Europe in the late 1830s, Christian Friedrich Schönbein (1799-1868) detected the same pungent odor, and realized that it was the smell that often follows a strong strike of lightning (Switzerland, 1999/*Scott* 1060). In 1840 he succeeded in isolating the gas and named it ozone, from the Greek *ozein* ("to smell"). For this reason, Schönbein is credited with the discovery of ozone.

By the early 1900s, researchers were convinced that most ozone is found in the stratosphere; we now know that 90 percent of atmospheric ozone is found in the stratosphere between ten and fifty kilometers. In 1924, the English scientist Gordon Miller Bourne Dobson (1889-1976) perfected an apparatus to measure total ozone in an atmospheric column. The instrument became known as the Dobson spectrophotometer (British Antarctic Territory, 1991/*Scott* 177), and the units used to measure ozone came to be known as "Dobson Units" (DU) (Cuba, 1992/*Scott* 3391). If all the ozone in the atmosphere were compressed down to a temperature of 0° C and at a pressure of one atmosphere, the resulting "slab" of ozone would normally be only about three millimeters thick, corresponding to 300 DU.

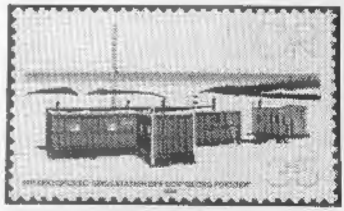
Measuring Ozone at Halley Bay
British Antarctic Territory (*Scott* 176)

By 1930, a photochemical theory of the formation and destruction of stratospheric ozone was being developed, and in 1934 one of the first balloon-borne ozone instruments showed that the maximum concentration of stratospheric ozone was at about 20 kilometers. In 1957 ozone measurements became part of the scientific activities of the International Geophysical Year (IGY), and the World Meteorological Organization (WMO) established the Global Ozone Observing System.

The first satellite-based ozone measurements became available in the 1960s. At that time, ozone research was focused on its properties as a tracer for stratospheric motions, and also as an absorber of solar ultraviolet (UV)



Ozone Values Provided in Dobson Units
Cuba (*Scott* 3391)



Ozone Data Collected In Antarctic
German Democratic Republic (*Scott* 3391)

radiation. This latter property was used to explain why temperature increases with height in the stratosphere. It also became more widely-understood that UV radiation at certain wavelengths was harmful to humans, animals, and plants, and thus that the ozone layer acts in effect to protect the planet from excessive UV radiation.

Measurement of Atmospheric Ozone

The Dobson spectrophotometer is still the backbone of global ozone monitoring with nearly 100 instruments in use around the world. The only source of long-term data about ozone comes from some of the Dobson-equipped stations. The oldest in Arosa, Switzerland, has a continuous record since 1925. Unfortunately, aerosols and atmospheric pollutants have a strong effect on Dobson measurements. In an attempt to minimize this problem, and also to avoid measuring ozone found in the lower atmosphere, some Dobson instruments have been located in mountaintop weather observatories, such as those at Pic du Midi (France, 1951/*Scott* 673), Zugspitze (Germany, 2000/*Scott* 2090), and Sonnblick (Austria, 1969/*Scott* 666 and 1986/1359). Dobson stations are also found in Antarctica, including those at Halley Bay (British Antarctic Territory, 1986/*Scott* 130, 1987/144 and 1991/176), and at New Zealand's Scott Base. A postal cancel of 1990 from Scott Base illustrates the relationship between chemistry and ozone research. Labelled "Antarctic Air Chemistry," it also shows a penguin holding an aerosol spray can.

Another instrument that has been used to measure ozone from the surface at various locations in the Antarctic is LIDAR (Light Detection and Ranging), which can be thought of as a laser radar (French Southern and Antarctic Territories, 1991/*Scott* C131).

Direct (or in-situ) measurements are available from three sources: scientific rockets, specially-instrumented aircraft, and ozonesonde balloons. There are launch covers of rockets with ozone-measuring equipment aboard, but no stamps are known to show such rockets together with a mention of ozone.

ER-2 Ozone Research Aircraft
British Antarctic Territory (*Scott* 179)

The ER-2 ozone research aircraft is illustrated on a stamp of the British Antarctic Territory (1991/*Scott* 179). One of the advantages of this particular aircraft, a converted U2 spy plane, is that it can fly at very high altitudes. Aircraft measurements are one aspect of "chemical studies in the ozone layer," as mentioned on this stamp.

Rockets and aircraft are expensive to operate, and require a specialized infrastructure. For this reason, the most common source of direct ozone measurements is the ozonesonde, a large balloon that carries specialized ozone-measuring instrumentation to heights of 20 kilometers or more (British Antarctic Territory, 1991/*Scott* 176; and French Southern and Antarctic Territories, 1991/*Scott* C115). Such balloons are used in ozone research throughout the world. Antarctica stations collecting ozonesonde data include Halley Bay and Georg Forster Station (German Democratic Republic, 1988/*Scott* 2667).

Satellite measurements of ozone have become more common and more important since the early 1960s. Interested readers will find a complete discussion of ozone-monitoring satellites in an article by the authors in the September/October 2003 issue of *The Astrophile*, the journal of the ATA Space Unit. The checklist from that article can also be found in the Ozone-Monitoring Satellites page in the authors' unmanned satellites Website at *<http://www.cira.colostate.edu/ramm/hillger/satellites.htm>*.

Balloons Measure Ozone Hole
French Southern and Antarctic Territories (*Scott* C115)

The Effect of CFCs and Halogens

Chlorofluorocarbons (CFCs) are a class of man-made compounds containing only chlorine, fluorine, and carbon. Similar compounds containing bromine are known as halons, while CFCs and halons together are known as halogens. In the past, halogens were found to be useful as cleaning solvents and aerosol spray can propellants (Chile, 1990/*Scott* 897, 1992/902, 988, 993; Ghana, 1999/*Scott* 2147; Kiribati, 1998/*Scott* 731; Netherlands, 1991/*Scott* 766; Norway, 2000/*Scott* 1260;

Screening Out Ultraviolet Rays
Chile (*Scott* 1165)

Molina's Ozone Depletion Equation
Mexico (*Scott* 2060)

and Panama, 1992/*Scott* 794). Another common application was in refrigeration and air conditioning (Ghana, 1999/*Scott* 2147) in which the CFC freon was often used (Maldives, 1990/*Scott* 1444). A souvenir sheet from Grenada-Grenadines (1991/*Scott* 1293) encourages us to "use natural coolers," presumably to avoid the CFCs from old-style air conditioners.

In the 1970s warning bells about CFCs were sounded, particularly in a 1974 article in the journal *Nature* in which Mario Jose Molina (born 1943) (Mexico, 1997/*Scott* 2060) and F. Sherwood Rowland (born 1927) argued that CFCs could be transported to the stratosphere where they would be broken down by solar energy. The resulting release of chlorine atoms would then favor ozone destruction through the now-famous equation:

$$C1 + O_3 \rightarrow C1O + O_2$$

The equation states that a chlorine (C1) atom combines with ozone (O_3) to yield chlorine monoxide (C10) and molecular oxygen (O_2). The graphic in a stamp from the British Antarctic Territory (1991/*Scott* 179) clearly shows the inverse relationship between chlorine monoxide and ozone: in regions where the chlorine monoxide concentration is high, ozone has been destroyed and its concentration is low. Where the chlorine monoxide concentration is low, the reaction has not taken place due to lack of chlorine, and the ozone concentration remains high.

The mechanism represented by this equation was validated by subsequent research, and in particular by the discovery of the Antarctic ozone hole in the early 1980s by the British Antarctic Survey (British Antarctic Territory, 1999/*Scott* 283). In recognition of their seminal work on this question, Molina and Sherwood, along with Paul J. Crutzen (born 1933), were awarded the 1995 Nobel Prize in Chemistry.

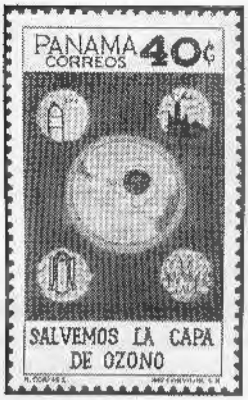
Stratospheric Ozone Depletion

The equation previously mentioned summarizes a complex series of photochemical catalytic reactions that cause ozone depletion. It turns out that the extremely cold temperatures of the Antarctic stratosphere are particularly favorable for such reactions; they are maximized in the Antarctic spring when the sun makes its reappearance and supplies the necessary energy to drive them. The chlorine monoxide molecule is unstable, and tends to break down releasing the chlorine atom which is then available to destroy another ozone molecule through the same reaction. This process goes on repeatedly, perhaps as many as 100,000 times for each chlorine atom which helps explain why the ozone depletion problem is so long-lived. It is now known that the bromine acts in the same way as chlorine, except that it is even more potent in ozone destruction.

Measurements show that ozone depletion is strongest at the Earth's mid-latitudes and in the polar regions. The problem is most severe in the Antarctic where an ozone "hole" appears in the stratosphere each austral spring (British Antarctic Territory, (1991/*Scott* 178 and 1999/283; Chile, 1991/*Scott* 974; Cuba, 1992/*Scott* 3391; French Southern and Antarctic Territories, 1991/*Scott* C115; Panama, 1992/*Scott* 794; and Tonga, 1990/*Scott* 737). Total column ozone values as low as 100 DU have been recorded under this hole. No similar holes have been found in other areas of the world.

Ozone Absorbs UV-B Radiation

One form of solar ultraviolet radiation (UV-B) can be harmful to humans, animals, and plants. Stratospheric ozone absorbs most UV-B radiation, and shields the surface of the Earth from it. Studies have clearly shown that, all other things being equal, a decrease in ozone in the atmosphere leads to increased UV-B amounts at the surface. This can lead to sunburn or worse, skin cancer. Other possible effects include eye cataracts, weakening of the immune system, and damage to DNA. It's no wonder that our mothers insist that we wear sunhats and use sunscreen to protect ourselves from the sun's rays (Chile,



Causes Producing the Ozone Hole
Panama (*Scott* 794)

Earth Crying Over Loss of Ozone
Ghana (*Scott* 2144)

1996/*Scott* 1165c). Marine life may also be damaged by excessive UV-B (Ghana, 1999/*Scott* 2143). Protecting the Earth from UV-B radiation is symbolically depicted on a stamp of Ghana (1999/*Scott* 2146).

The International Response

The discovery of the ozone hole and worry about the effects on life of the resulting increased UV-B radiation led to international action. A United Nations working group was set up in 1981 with the aim of preparing a global framework for the protection of the ozone layer. This work led to the Vienna Convention of 1985 in which 20 nations agreed to protect the environment from human activities likely to modify the ozone layer, even though no specific measures were adopted.

The gravity of the problem became clearer through continuing ozone research in the mid-1980s. An agreement with some "teeth" was clearly necessary, and in 1987 the international community agreed to a plan for reducing use of halogens under the landmark Montreal Protocol. Subsequent amendments in the 1990s (London, Copenhagen, Montreal, and Beijing) strengthened the Protocol. By the tenth anniversary of the Protocol in 1997 there were hints that actions stemming from it were beginning to have a positive effect (Bahrain, 1997/*Scott* 497-500; Belarus, 1991/*Scott* 210a; Egypt, 1997/*Scott* 1652-1653; Iran, 1997/*Scott* 2710; Peru, 1997/*Scott* 1156; St. Vincent, 1997/*Scott* 2488; and Saudi Arabia, 1997/*Scott* 1265-1266).

By the thirteenth meeting of the parties to the Montreal Protocol in 2001, measurements were starting to provide the proof (Sri Lanka, 2001/*Scott* 1349). Estimates from 2002 are that stratospheric chlorine is at or near its peak, although bromine is likely still increasing. Clearly, the Protocol is working, and has become a major international success story. However, we are not out of the woods yet. The ozone layer is still vulnerable, and it will take up to another decade to see a clear signal that stratospheric ozone has begun to recover. How long will it take for the ozone layer to return to its original state? The best current estimates are that it will take another 50 years.

World Ozone Day

The Montreal Protocol was signed on September 16, 1987. To publicize the ozone depletion problem and the efforts marshalled to correct it, the United Nations sponsored the International Day for the Preservation of the Ozone Layer (sometimes called World Ozone Day) each September 16 since 1995 (Brazil, 2000/*Scott* 2761; Croatia, 1999/*Scott* 408; Egypt, 1995/*Scott* 1595-1597 and 1997/1622-1623; Mexico, 1996/*Scott* 2015; Russia, 1997/*Scott* 6415; and Salvador, 1997/*Scott* 1464).

Many other stamps present a general message to the public about protecting the ozone layer (Argentina, 1998/*Scott* 1989; Chad, 1998/*Scott* 765-768; Great Britain, 1992/*Scott* 1464; Jordan, 1997 /*Scott* 1554; Kazakhstan, 1999/*Scott* 283; Kuwait, 1997/*Scott* 1369-71; Mozambique, 1997/*Scott* 1293; Pakistan, 1997/*Scott* 882; and Panama, 1992/*Scott* 794). No such stamps have been issued by Canada or the U.S.A. However, cancellations from two U.S. post offices are available to the collector (Ozone, Tennessee; and Ozone, Arkansas).

Ground-Level Ozone

Some emissions from industry and motor vehicles react with sunlight to produce ozone near the ground. This ozone causes respiratory problems and has been increasing in recent years. It is one component of the infamous smog sometimes found near big cities. Ground-level ozone is very different from the

Controlling Depletion of Ozone
Peru (*Scott* 1156)

Creating the Greenhouse Effect
Kiribati (*Scott* 731)

"good" stratospheric ozone that protects us from UV-B radiation. No stamps are known to clearly refer to ground-level ozone or smog. However, many stamps with a general air pollution theme do exist, and some of them depict emissions from industrial smokestacks or motor vehicles. Such emissions can contribute to ground-level ozone and smog.

Ozone and Climate Change

Both ozone and halogens are greenhouse gases. The recent decrease in the amounts of stratospheric ozone has had a small cooling effect, but it has been swamped by the warming due to the increases in concentrations of the main greenhouse gases — carbon dioxide (CO_2) and methane. Increasing concentrations of halogens throughout the atmosphere, and of ozone in the troposphere, also tend to warm the planet, but their effect is smaller than that of the principal greenhouse gases.

The relationship between ozone and climate change is complicated, so it should not be surprising that some stamps give incomplete or even misleading messages in this area. For example, a stamp from Grenada-Grenadines (1991/*Scott* 1298) is inscribed, "Protect the ozone layer, plant more trees." More trees would remove CO_2 from the atmosphere and thus decrease the greenhouse warming. However, the relation between climate change and ozone is not clear.

A stamp from Tonga (1990/*Scott* 737) informs us that "Ice caps [are] in danger as holes in the ozone layer grow." This message is presumably related to the greenhouse warming due to the halogens that caused the ozone hole in the first place. However, the warming due to increased CO_2 is much greater than that due to the increased halogens. A more balanced treatment is found on stamps of Maldives (1990/*Scott* 1444) and Kiribati (1998/*Scott* 731), both of which depict the theme of global warming and the greenhouse effect. On the Maldives stamp, the CFC freon is mentioned in addition to the traditional causes of global warming (forest burning, fuel burning, and methane). The Kiribati stamp shows auto exhaust and smokestacks to symbolize the release of CO_2 but it also depicts an aerosol spray can to indicate the release of halogens into the atmosphere.

Ozone depletion is like a disease of the Earth (symbolized on Ghana, 1999/*Scott* 2145). However, this disease is unusual in that its cause and its solution are one and the same, namely human activity. Since the disease recognizes no political boundaries, policy decisions at the international level based on science have been imperative in creating the antibodies that are beginning to fight the disease. This example of successful international cooperation shows what can be accomplished on the world stage, and could be considered a model for future international action in other areas. We owe it to the children of the world to protect the ozone layer (symbolized on Argentina, 1998/*Scott* 1989; and Great Britain, 1992/*Scott* 1464 in the context of ozone).

A checklist of all known stamps and postal items related to ozone can be found on the Ozone page of the authors' weather Website: *<http://www.cira.colostate.edu/ramm/hillger/weather.htm>*

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